

INTERSTELLAR GRAIN CHEMISTRY AND THE COMPOSITION OF COMETS

L. J. Allamandola, S. A. Sandford, and F. P. J. Valero
 NASA-Ames Research Center, Mail Stop 245-6
 Moffett Field, CA 94035

167707
 23

During the past 15 years considerable progress in observational techniques has been achieved in the middle infrared ($5000-500 \text{ cm}^{-1}$, $2-20\mu\text{m}$), the spectral region most diagnostic of molecular vibrations. Spectra of many different astronomical infrared sources, some deeply embedded in dark molecular clouds, are now available. These spectra provide a powerful probe, not only for the identification of interstellar molecules in both the gas and solid phases, but also of the physical and chemical conditions which prevail in these two very different domains.

By comparing these astronomical spectra with the spectra of laboratory ices, one can determine the composition and abundance of the icy materials frozen on the cold (10 K) dust grains present in the interior of molecular clouds (Tielens *et al.*, 1984; Tielens and Allamandola, 1987). These grains and their ice mantles may well be the building blocks from which comets are made. Thus, it is possible to learn something about the cometary materials by studying the photochemistry of interstellar ice analogs in the laboratory.

In the experiments described here we proceed with the assumption that cometary ices are similar to (and probably derived from) interstellar ices. As an illustration of the processes which can take place as an ice is irradiated and subsequently warmed, we present the infrared spectra of the mixture $\text{H}_2\text{O}:\text{CH}_3\text{OH}:\text{CO}:\text{NH}_3:\text{C}_6\text{H}_{14}$ (100:50:10:10:10). Apart from the last species, the ratio of these compounds is representative of the simplest ices found in interstellar clouds. The last component was incorporated into this particular experiment as a tracer of the behavior of a non-aromatic hydrocarbon. Figure 1 shows the change in the composition that results from ultraviolet photolysis of this ice mixture using a UV lamp to simulate the interstellar radiation field. Photolysis produces CO , CO_2 , CH_4 , HCO , H_2CO , as well as a family of moderately volatile hydrocarbons. As can be seen in Figures 2 and 3, less volatile carbonaceous materials are also produced.

Figure 2 shows the evolution of the infrared spectrum of the ice as the sample is warmed up to room temperature. We believe that the changes are similar to those which occur as ice is ejected from a comet and warmed by solar radiation. The warm-up sequence shows that the nitrile- or iso-nitrile ($-\text{C}\equiv\text{N}$ or $\text{C}\equiv\text{N}-$)-bearing compound produced during photolysis evaporates between 200 and 250 K, suggesting that it is carried by a small molecular species. These molecules could be similar to the source material on comet Halley that is ejected in grains into the coma, freed by sublimation, and photolyzed by solar radiation to produce the observed $\text{C}\equiv\text{N}$ jets. The presence of several different types of $-\text{CH}_3$ and $-\text{CH}_2$ -bearing molecules in the residues is indicated by the spectral structure in the $3000-2700 \text{ cm}^{-1}$ ($3.3-3.6\mu\text{m}$) region (Fig. 3). The profile and position of the " $3.4\mu\text{m}$ " emission feature in comet Halley indicates that the carrier of the cometary band is dominated by $-\text{CH}_3$ groups, while the band observed towards the galactic center and in this laboratory experiment indicates the presence of $-\text{CH}_2$ -dominated hydrocarbons (comet Halley: see papers by Danks, Tokunaga, and others in this report, as well as Baas, Geballe, and Walther, 1986; Galactic Center: see Allan and Wickramasinghe, 1981, and Jones *et al.*, 1983).

References

Allen, D. A. and Wickramasinghe, D. T., 1981, *Nature*, **294**, 239.
 Baas, F., Geballe, T. R., and Walther, D. M., 1986, *Astrophys. J.*, **311**, L97.
 Jones, T. J., Hyland, A. L., and Allen, D. A., 1983, *Mon. Not. Roy. Soc.*, **205**, 187.
 Tielens, A. G. G. M. and Allamandola, L. J., 1987, in *Physical Processes in Interstellar*

PHOTOCHEMICAL EVOLUTION OF
 $\text{H}_2\text{O} : \text{CH}_3\text{OH} : \text{NH}_3 : \text{CO} : \text{C}_6\text{H}_{14}$
 100 : 50 : 10 : 10 : 10

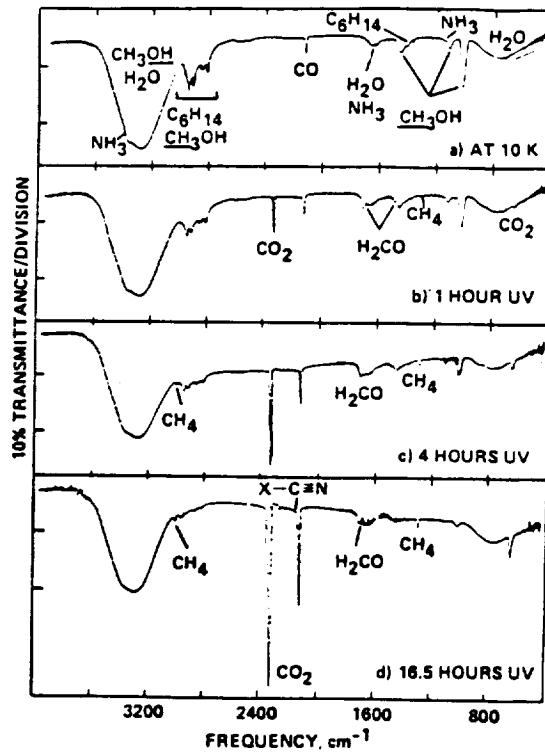


FIGURE 1

WARM-UP BEHAVIOR OF LOW VOLATILITY
 RESIDUE PRODUCED BY 15 HOURS
 PHOTOLYSIS OF $\text{H}_2\text{O} : \text{CH}_3\text{OH} : \text{CO} : \text{NH}_3 : \text{C}_6\text{H}_{14}$
 100 : 50 : 10 : 10 : 10

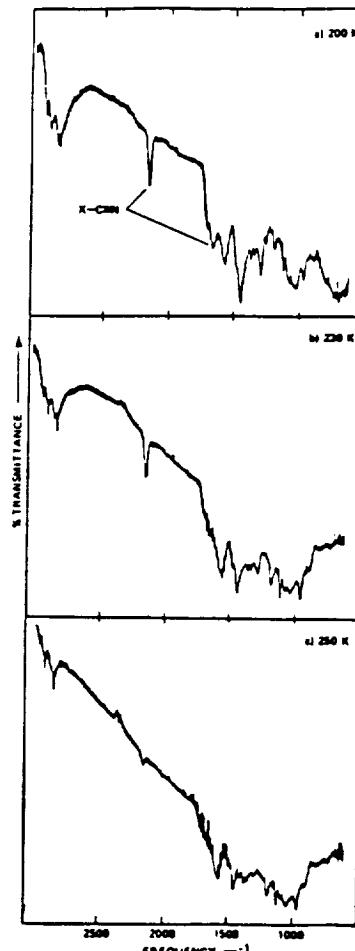


FIGURE 2

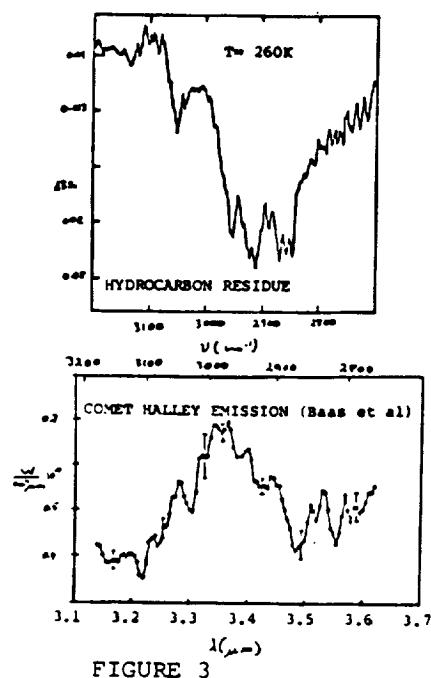


FIGURE 3

ORIGINAL PAGE IS
 OF POOR QUALITY